

# Charged Higgs production with a top quark at the LHC<sup>1</sup>

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## Abstract

I discuss charged Higgs production via the process  $bg \rightarrow tH^-$  at the LHC. I show that the cross section is dominated by soft-gluon corrections and I provide results for its dependence on the charged Higgs mass and on the scale, including higher-order effects.

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# 1 Introduction

A future discovery of a charged Higgs boson would be a sure sign of new physics beyond the Standard Model. The Minimal Supersymmetric Standard Model (MSSM) includes in its particle content charged Higgs bosons in addition to neutral Higgs. The discovery of the Higgs boson, including the charged Higgs of the MSSM, is a major goal at the Tevatron and the LHC.

The LHC has good potential for discovery of a charged Higgs. A promising channel is  $bg \rightarrow tH^-$  [1, 2, 3]. The complete next-to-leading order QCD corrections to this process have been recently derived in Refs. [4, 5].

The Born cross section is proportional to  $\alpha\alpha_s(m_b^2 \tan^2 \beta + m_t^2 \cot^2 \beta)$ . Here  $\tan \beta = v_2/v_1$  is the ratio of the vacuum expectation values of the two Higgs doublets in the MSSM. We use the  $\overline{\text{MS}}$  running top and bottom quark masses, corresponding to pole masses  $m_t = 175$  GeV and  $m_b = 4.8$  GeV, in the  $\tan^2 \beta$  and  $\cot^2 \beta$  terms, but set  $m_b = 0$  elsewhere.

## 2 Charged Higgs NNLO-NLL cross section

The production cross section for  $b(p_b) + g(p_g) \rightarrow t(p_t) + H^-(p_{H^-})$  at the LHC for large  $m_{H^-}$  is actually dominated by soft-gluon corrections from the near-threshold region [3, 6]. We define the standard kinematical invariants  $s = (p_b + p_g)^2$ ,  $t = (p_b - p_t)^2$ ,  $u = (p_g - p_t)^2$ , and  $s_4 = s + t + u - m_t^2 - m_{H^-}^2$ . At threshold  $s_4 \rightarrow 0$ . The threshold soft-gluon corrections then take the form  $[\ln^l(s_4/m_{H^-}^2)/s_4]_+$ , with  $l \leq 2n - 1$  for the order  $\alpha_s^n$  corrections. They are calculated following the methods in Refs. [7, 8], which have been applied to various processes [9, 10]. The leading logarithms (LL) are with  $l = 2n - 1$  while the next-to-leading logarithms (NLL) are with  $l = 2n - 2$ . Here we calculate NLO and NNLO soft-gluon corrections at NLL accuracy. We denote them as NLO-NLL and NNLO-NLL, respectively. Thus, at NLO we include  $[\ln(s_4/m_{H^-}^2)/s_4]_+$  (LL) and  $[1/s_4]_+$  (NLL) terms. Although we do not include the full virtual  $\delta(s_4)$  terms, we include those  $\delta(s_4)$  terms that involve the factorization and renormalization scales, denoted by  $\mu$ . At NNLO, we include  $[\ln^3(s_4/m_{H^-}^2)/s_4]_+$  (LL) and  $[\ln^2(s_4/m_{H^-}^2)/s_4]_+$  (NLL) terms. We also include some  $[\ln(s_4/m_{H^-}^2)/s_4]_+$  and  $[1/s_4]_+$  terms that involve the scale  $\mu$  and some  $\zeta_2$  and  $\zeta_3$  constants. Explicit analytical expressions are given in [3].

In Fig. 1 we plot the cross section for charged Higgs production via  $bg \rightarrow tH^-$  at the LHC as a function of the charged Higgs mass for  $\tan \beta = 30$  and  $\mu = m_{H^-}$ . The approximate NNLO parton distributions of Ref. [11] have been used. We note that in the corresponding figures in Refs. [3, 6] the pole mass of the bottom quark was used; the  $\overline{\text{MS}}$  mass, however, is a preferable choice [5]. The Born, NLO-NLL, and NNLO-NLL cross sections are shown. The cross sections span over two orders of magnitude in the mass range  $200 \text{ GeV} \leq m_{H^-} \leq 1000 \text{ GeV}$ .

In Fig. 2 we plot the  $K$ -factors, i.e. the ratios of the NLO-NLL and NNLO-NLL cross sections to the Born cross section, and the ratio of the NNLO-NLL to the NLO-NLL cross section. We use the same NNLO parton densities and couplings at all orders, so as

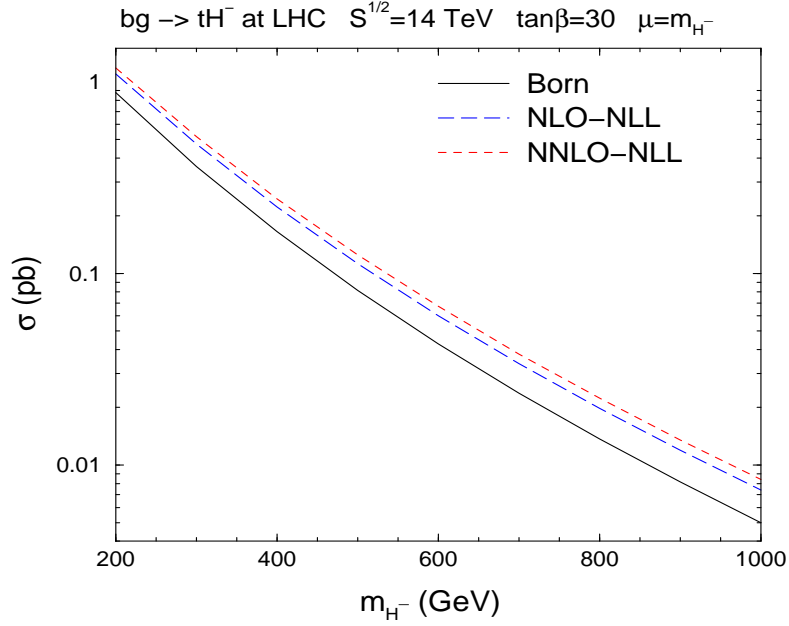


Figure 1: Charged Higgs production cross section versus charged Higgs mass.

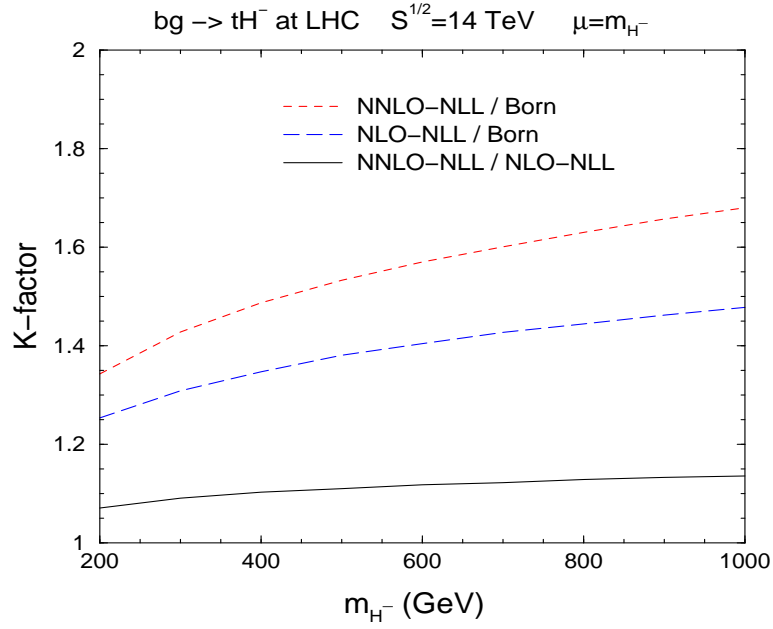


Figure 2:  $K$ -factors versus charged Higgs mass.

to concentrate on the effect of the soft-gluon corrections. It should be stressed that the NLO-NLL/Born ratio is quite close to the exact NLO/Born ratio [4, 5] (note that different conventions and scales are used there) which indicates that threshold corrections indeed

dominate the cross section. The difference between the exact NLO and NLO-NLL results is only a few percent. The NNLO-NLL corrections provide a significant enhancement to the NLO cross section.

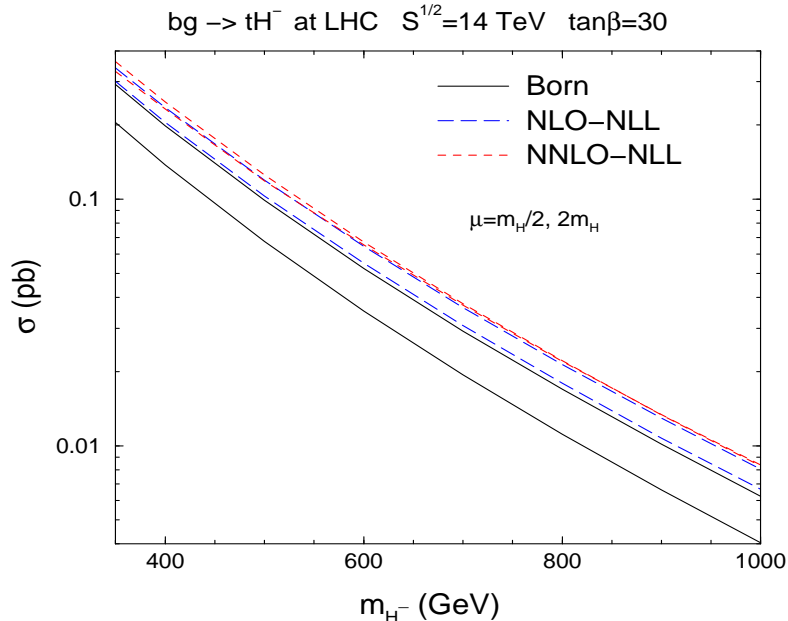


Figure 3: The scale dependence of charged Higgs production cross sections.

In Fig. 3 we plot the cross section with two different choices of scale,  $\mu = m_{H^-}/2$  and  $2m_{H^-}$ . For clarity we concentrate on  $m_{H^-} \geq 350$  GeV. We see that the variation with scale of the Born cross section is large. The variation at NLO-NLL is smaller, and at NNLO-NLL it is very small. In fact the two NNLO-NLL curves are on top of each other for most of the range in  $m_{H^-}$ . Hence, the scale dependence of the cross section is drastically reduced when higher-order corrections are included.

Finally, we note that the cross section for  $\bar{b}g \rightarrow \bar{t}H^+$  is the same as for  $bg \rightarrow tH^-$ .

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